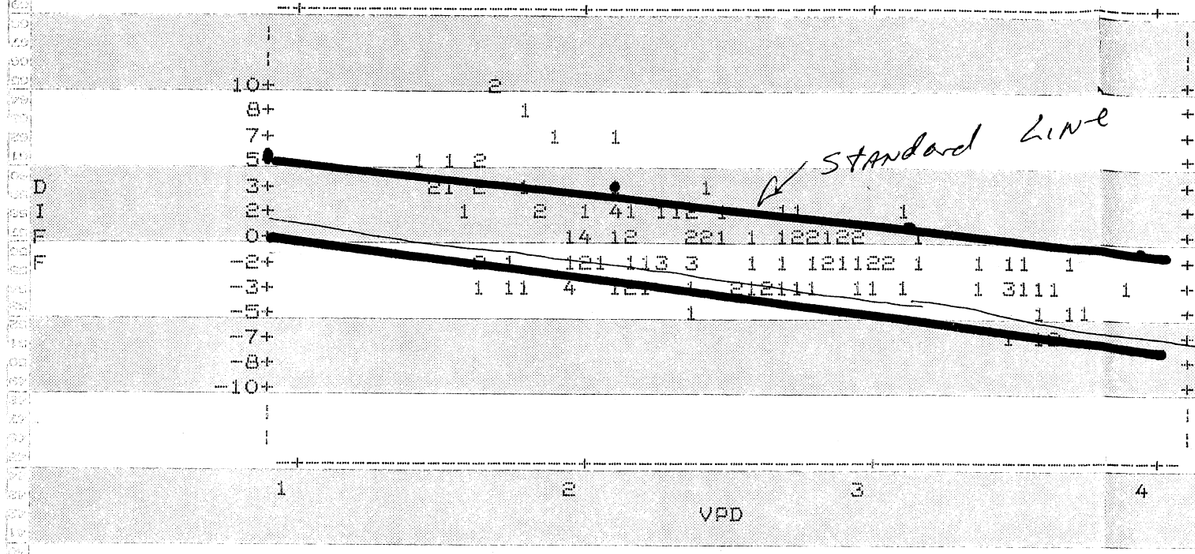
Date/Time 02-25-1987 10:33:57
Data Base Name A:data
Description Imported from A:turf.dat

Scatter Plots

WINTER TURF DATA
X (VPD) by Y (DIFF) = Frequencies



7 - 1.9 * VPD upper = 13

2.0 - 1.9 * VPD upper = 8

OR

3.0 - 1.9 * VPD upper = 9

In order to comprehensively understand the behavior of the ST-27 index on turf grass, the following questions need to be answered There are six major categories of questions:

- Grass type/mixtures
- Management Practices/Design Considerations
- Soil Water
- Theoretical
- Interpretation
- Agronomic

Grass Type/Mixtures

- how does grass type (cool season, warm season),species (bermudas, fescue, etc) and variety affect the index?
grass specie-- (bermuda, fesuce, St. Augustine, etc., etc.)
grass variety-- (Penncross bermuda, Emerald bermuda , Toronto bermuda, etc, etc, etc, for each grass specie).

- What is the effect of grass mixtures on the turf index?

- How does naturally occuring dormancy affect the index? What is the effect of a mixture of dormant and rapdily growing species on the index?

Management Practices/Design Considerations

- Grass useage--is the grass subjected to frequent traffic, such as a practice putting green, or is it seldom walked on (parks) by comparison?

- cutting height--given that all other factors remain the same, how does cutting height affect the index?

- does the type/sharpeness of lawn mower used to cut the turf have an effect?

- how much do grass clippings (of what density?) affect the index?

- What effect does thatch have? how does this effect interact with Plant type, plant thickness, and surface wetness?

- What is the effect of variations in plant density? How does this effect interact with surfact soil wetness or dryness? How does this effect interact with windspeed?

- how does slope and aspect affect the index? Are differences in the index on sloped areas versus flat areas the result of seeing more thatch/soil or is there also a "real" effect, i.e., do sloped areas actual experience more(or less) stress, depending on their exposure to the sun? How does this affect index readings/mangement concerns on a green?

Benson,

I have received, we should visit briefly about this subject.

Steve

• cultivation practices--how does coring, top-dressing, vertical mowing, matting, adding wetting agents, etc. affect the index?

•What is the optimum irrigation timing sequence for a given type of turf, as a function of soil type, location, and useage? Can these timing sequences be inferred from index readings? How can "optimum" be defined?

•What management solutions are available for localized "hot spots" identified by the ST-27? Irrigating a hot spot via adjusted sprinkler patterns may result in waterlogging adjacent areas, which in turn would make the adjacent areas warmer. How detrimental is this? Must a green be rebuilt in order to effectively eliminate some hot-spots?

• what effect does mowing frequency have on the index?

• how does syringing interact with the index? Can the index be used after a syringing for any useful purpose?

• can sprinkler head distribution patterns be effectively judged with the index? How?

Soil Water

• how do index readings compare with tensiometer/soil moisture readings?

• how does salinity in the soil and water affect the index ?

• What is the effect of soil PH on the index?

• What is the relationship between morning dew patterns and afternoon turf temperature patterns? Morning dew patterns represent a competiting technology to find the dry spots on a green.

This is not A technology it is A phenotipic method. Subjective method. ("Best guess")

• What is the effect of soil oxygen depletion on the index? How long does this effect last? How long does it take for this effect to produce changes in visual quality (low index numbers, with poor visual characteristics).

• irrigation practices--how does the style of irrigation interact with index values ? How dependent is this on site specific soil characteristics and climatic conditions?

Theoretical

• What effect does windspeed have on the index? Under what conditions?

• What is the effect of air temperature on all the above interactions?

• how do index readings compare with soil temperature readings?

Interpretation

. is a turf with poor visual qualities, but low index readings currently in the "recovery" mode?

. how long does it take a particular grass species to recover good visual appearance after its visual characteristics have been impaired? How does this interact with the index?

. what is the best standard with which to compare visual quality and agronomic health between turf located at different sites?

. how does over-irrigation impact the index and turf quality, especially over time? Does this predispose an area to having problems if water supplies suddenly become restricted?

. visual quality--what is the relationship between visual quality , the turf index and all the above variables.

Agronomic Concerns

.disease effects on turf temperature -- is the disease fast acting (overnight) or does it develop over time, with a corresponding effect on plant temperatures? Does the disease affect plant temperatures?

. fertilizer effects--what is the effect on plant temperatures of turf that is short in N,P,K or various micronutrients?

. chemical effects--what happens to plant temperatures when various funsicides and insecticides are applied?

.How does the index work on grasses which grow primarily in the shade?

. What is the optimum rooting depth for a turf species? Can rooting depth be controlled with the index? How does time of year interact with this objective?

. How does the optimum biological temperature of a grass species interact with the index and all the above? What is the optimum biological temperature for a given grass species, or grass mixture?

. what is the effect of auotrphic and heterotrophic bacteria?

? & I don't understand.

ST27 ANALYSIS SOFTWARE
PRODUCTION VERSION

VERSION 2.0
COPYRIGHT FEBRUARY, 1989

I. Purpose

The purpose of this program is to allow a user to easily down-load the data in a ST27
to a personal computer and to analyze it graphically or in tabular form.

****
caution : do not proceed with these instructions unless you have made a back-up copy of the program disk !!!
See your DOS manual for the DISKCOPY procedure.
****

II. Set-Up Procedure

---
create a sub-directory for your programs

C: drives only

Copy your program disk into a sub-directory. For example, to copy your program disk into the sub-directory PROD :

```
c:
cd\
mkdir PROD
cd\PROD
```

then place your program disk in the A: drive and

```
copy A:*.*
```

your program disk now has been copied into the subdirectory PROD.

Running the Program

For A: Drives:

Place your program disk in the A: drive and type MENU.
If you want to store youre data on the B: drive, then insert a formatted disk into the B drive.

For C: Drives:

Place a formatted disk in the A: drive if you elected to store your data on a floppy disk during the set-up procedure.

Issue the commands :
C:
cd\PROD
MENU

OPTIONS*

Option 1. "IMPORT". This option will allow you to import data directly into a temporary file called "TODAY.TMP".

Option 2. "PRINT". This option will allow to examine the data you have imported to make sure it is correct. If you make a mistake, simply return to option 1 and re-import the files.

Option 3. "TODAY". When you are satisfied that you have properly imported the data file, select option 3. The file you have imported will be converted to a form useable by the program. The contents of the temporary file "TODAY.TMP" will be also be archived into the permanent file TODAY.DAT. If this is the first time you have used the program, or if you have erased the file, the program will automatically create the permanent data file. The data will be stored without any alpha-characters.

Option 4. "PATTERNS". This option will produce a report which shows the pattern of temperatures observed by the ST27. This report is the key to making the ST27 provide valuable management information. An analysis data-base called "HIST.DAT" is automatically updated and included in the report.

5. Option 5. "Graph ". This option will allow you to plot today's data. You must run option 3 first to create the graphic file. You select which graph to see:
The program can plot any of the following variables on either axis:

#1 Turf Temperature versus Green Number (visually shows the variation in turf temperatures)

#2 Stress Index versus Green Number (visually shows the variation in stress index)

#3 Air Temperature versus time
#4 Relative Humidity versus time
#5 Sunlight Reading versus time
Graphs 3-5 allow you to asses the environmental changes which occured during the sample period.

OTHER OPTIONS

"S" allows you to SET-UP a file called "SETUP.DAT" which tells your computer the following:

- the NAME of your Golf Course
- the disk drive your programs are stored on
- the disk drive to store your data on
- whether your ST27 records temperature in Farenheit or in Celsius
- whether or not to initialize a new analysis data base. This option allows you to "start-over" at any time.

"Q" to quit the program. This option is available from the main menu only.

Sample Data Files

The program disk contains the sample files "TODAY.SAM"and "TD.TMP". These files contain real data from the Grantwood golf course in Solon, Ohio. If you wish to run the program without actually conntecting a St27 and down-loading a real data set, issue the following commands.

C: drives
place your program disk in the A: drive
c:
cd\PROD
copy a:TODAY.SAM c:TODAY.TMP
copy a:TD.SAM c:TD.TMP
from the C: drive, type MENU

A: drives
place your program disk in the A: drive.
copy TODAY.SAM TODAY.TMP
copy TD.SAM TD.TMP
or copy TODAY.SAM b:TODAY.TMP and copy TD.TMP , If you are storing your data on the B drive.
MENU

except for the IMPORT option, you will be able to run the program and make plots. You will be able to start directly at Option 4 (Pattern analysis). If you run the import option, you will erase the .TMP file. It will then be necessary to recopy the sample data into these files to run the program.

The file TODAY.TMP contains data in this format :

AREA DATA FOR 08/17/88

--- AREA ---	TIME	AVERAGES TURF	AIR	RH	SUN	STRESS INDEX	SAMPLES TAKEN
01 FRONT	12:15	+090	+091	50	084	-02.5	14
LEFT	12:16	+092	+092	51	079	-02.1	12
MIDDLE	12:17	+090	+091	49	082	-02.5	14
RIGHT	12:17	+093	+092	49	086	-01.1	14
BACK	12:18	+092	+092	49	078	-01.9	16
02 FRONT	12:23	+089	+092	49	081	-03.3	11
LEFT	12:24	+098	+091	49	083	+01.6	08
MIDDLE	12:26	+091	+093	50	080	-02.8	13
RIGHT	12:27	+089	+093	48	083	-03.2	12
BACK	12:28	+088	+092	47	086	-03.5	14
03 FRONT	12:30	+093	+092	50	087	-01.2	13
LEFT	12:32	+093	+093	47	085	-01.6	10
MIDDLE	12:33	+093	+094	45	090	-01.5	12
RIGHT	12:34	+097	+092	48	086	+00.5	10
BACK	12:35	+093	+094	49	081	-01.9	10
04 FRONT	12:37	+090	+092	47	082	-02.6	15
LEFT	12:38	+090	+093	47	085	-02.8	14
MIDDLE	12:38	+089	+093	48	087	-03.6	17
RIGHT	12:39	+091	+093	48	084	-02.7	15
BACK	12:40	+089	+093	48	081	-03.4	14
05 FRONT	12:42	+086	+092	49	048	-04.7	17
LEFT	12:43	+086	+093	49	051	-05.3	11
MIDDLE	12:44	+084	+092	48	049	-05.7	12
RIGHT	12:44	+086	+091	49	045	-04.5	13
BACK	12:45	+083	+091	50	041	-05.9	12
06 FRONT	12:51	+089	+090	51	045	-03.1	10
LEFT	12:52	+087	+090	50	051	-03.6	08
MIDDLE	12:52	+085	+090	52	052	-05.1	11
RIGHT	12:53	+084	+091	51	061	-05.6	14
BACK	12:54	+084	+090	50	062	-05.2	15
07 FRONT	12:57	+091	+092	52	077	-02.8	17
LEFT	12:57	+091	+092	51	075	-02.8	13
MIDDLE	12:59	+089	+093	46	086	-03.3	16
RIGHT	13:00	+091	+093	47	082	-02.2	17
BACK	13:02	+094	+092	50	090	-00.7	12
08 FRONT	13:05	+089	+093	47	084	-03.1	20
LEFT	13:06	+090	+094	48	090	-03.0	17
MIDDLE	13:07	+089	+094	47	087	-03.5	17
RIGHT	13:08	+099	+094	46	093	+01.1	19
BACK	--- No samples taken ---						

The file TODAY.DAT contains a file like this :

```
01,FRONT ,12,15,090,091, 50,084,-02.5, 14,08,17,88
01,LEFT  ,12,16,092,092, 51,079,-02.1, 12,08,17,88
01,MIDDLE,12,17,090,091, 49,082,-02.5, 14,08,17,88
01,RIGHT ,12,17,093,092, 49,086,-01.1, 14,08,17,88
01,BACK  ,12,18,092,092, 49,078,-01.9, 16,08,17,88
02,FRONT ,12,23,089,092, 49,081,-03.3, 11,08,17,88
02,LEFT  ,12,24,098,091, 49,083, 01.6, 08,08,17,88
02,MIDDLE,12,26,091,093, 50,080,-02.8, 13,08,17,88
02,RIGHT ,12,27,089,093, 48,083,-03.2, 12,08,17,88
02,BACK  ,12,28,088,092, 47,086,-03.5, 14,08,17,88
03,FRONT ,12,30,093,092, 50,087,-01.2, 13,08,17,88
03,LEFT  ,12,32,093,093, 47,085,-01.6, 10,08,17,88
03,MIDDLE,12,33,093,094, 45,090,-01.5, 12,08,17,88
03,RIGHT ,12,34,097,092, 48,086, 00.5, 10,08,17,88
03,BACK  ,12,35,093,094, 49,081,-01.9, 10,08,17,88
04,FRONT ,12,37,090,092, 47,082,-02.6, 15,08,17,88
04,LEFT  ,12,38,090,093, 47,085,-02.8, 14,08,17,88
04,MIDDLE,12,38,089,093, 48,087,-03.6, 17,08,17,88
04,RIGHT ,12,39,091,093, 48,084,-02.7, 15,08,17,88
04,BACK  ,12,40,089,093, 48,081,-03.4, 14,08,17,88
05,FRONT ,12,42,086,092, 49,048,-04.7, 17,08,17,88
05,LEFT  ,12,43,086,093, 49,051,-05.3, 11,08,17,88
05,MIDDLE,12,44,084,092, 48,049,-05.7, 12,08,17,88
05,RIGHT ,12,44,086,091, 49,045,-04.5, 13,08,17,88
05,BACK  ,12,45,083,091, 50,041,-05.9, 12,08,17,88
06,FRONT ,12,51,089,090, 51,045,-03.1, 10,08,17,88
06,LEFT  ,12,52,087,090, 50,051,-03.6, 08,08,17,88
06,MIDDLE,12,52,085,090, 52,052,-05.1, 11,08,17,88
06,RIGHT ,12,53,084,091, 51,061,-05.6, 14,08,17,88
06,BACK  ,12,54,084,090, 50,062,-05.2, 15,08,17,88
07,FRONT ,12,57,091,092, 52,077,-02.8, 17,08,17,88
07,LEFT  ,12,57,091,092, 51,075,-02.8, 13,08,17,88
07,MIDDLE,12,59,089,093, 46,086,-03.3, 16,08,17,88
07,RIGHT ,13,00,091,093, 47,082,-02.2, 17,08,17,88
07,BACK  ,13,02,094,092, 50,090,-00.7, 12,08,17,88
08,FRONT ,13,05,089,093, 47,084,-03.1, 20,08,17,88
08,LEFT  ,13,06,090,094, 48,090,-03.0, 17,08,17,88
08,MIDDLE,13,07,089,094, 47,087,-03.5, 17,08,17,88
08,RIGHT ,13,08,099,094, 46,093, 01.1, 19,08,17,88
```

Effective 11/15/89

SCHEDULER DISTRIBUTORS

	PHONE	FN	COMPANY	ADDRESS	ADDRESS2	CITY	ST	ZIP
1	602/853-0077	Steve Carl	CCT Corporation	4354 N. Cotton Lane		Avondale	AZ	85340
2	209/333-1599	Mike Manna	Acampo Ag Service	775 E. Acampo		Acampo	CA	95220
3	209/221-1476	Ron Brase	Applied Technology Prod.	1557 W. Shaw		Fresno	CA	93711
4	805/922-6943	William Bogue	Pacific Ag Water Inc.	P. O. Box 1874	1520 E. Donovan Rd	Santa Maria	CA	93456
5	912/874-9700	Elton Sharp	Sharp Systems Inc.	Hwy. U.S. 280		Leslie	GA	31764
6	208/425-3585	Bart Christensen	Kenneth O. Christensen Farms	Rte. 1, Box 40		Grace	ID	83241
7	601/332-3555	Johnny McRight	McRight Agri-Management	PO Box 4812	VFW Road	Greenville	MS	38704-4812
8	806/935-7765	Jerry Wakefield	Circle L Irrigation	Etter Route, PO Box 97D		Dumas	TX	79029
9	806/272-4483	Don McElroy	Irrig. Pump & Power Inc.	Box 313		Muleshoe	TX	79347
10	509/488-2807	Dale Bowers	Crop Care Inc.	1155 South Broadway		Othello	WA	99344

SCHEDULER SALES REPS

	PHONE	FN	COMPANY	ADDRESS	ADDRESS2	CITY	ST	ZIP
1	208/549-0353	Jack Terry	Mincron	P. O. Box 685	1064 Olds Ferry Road	Weiser	ID	83672
2	916/343-4714	Paul Arends	P & P Sales	3556 Callie Principle		Chico	CA	95926
3	707/963-8727	Steven Soper	The Water Works	P. O. Box 446		Rutherford	CA	94573
4	408/455-1391	John Sandys	IrriDrain	30 Hitchcock Road	P.O. Box 2022	Salinas	CA	93902
5	209/874-1654	Erie Clifton		641 Timbell Road		Waterford	CA	95375
6	619/353-5025	W. F. (Bill) North		1738-C Olive Avenue		El Centro	CA	92243
7	505/525-1545	Alfred L. Trujillo	T & N International Inc.	P. O. Box 6374	1924 Highland	Las Cruces	NM	88006
8	806/864-3314	Darrell Holley	Holley Fertilizer	HCOI, Box 41		Plainview	TX	79072
9	806/747-3133	Haynes Melton	Caprock Garden Seeds	P. O. Box 53004		Lubbock	TX	79453

ST27 DISTRIBUTORS

	PHONE	FN	COMPANY	ADDRESS	ADDRESS2	CITY	ST	ZIP
1	602/277-1300	Bernie Atutis	Karsten Mfg Corporation	2201 West Desert Cove	P. O. Box 9990	Phoenix	AZ	85029
2	213/865-9541	Lon Records	Target Specialty Products Inc.	17710 Studebaker Road	Box 1117	Cerritos	CA	90701
3	213/459-4412	John Keeling	Turf Technology Co.	P. O. Box 160	437 Puerto Del Mar	Pacific Palisades	CA	90272
4	312/668-5537	Walter Fuchs	Turf Products Limited	2N255 County Farm Road		West Chicago	IL	60185
5	313/437-1427	Eugene Johanningsmeier	Turf Grass Inc.	P. O. Box T365	Woodland Drive	South Lyon	MI	48178
6	516/924-0454	Lance Authelet	AWI Golf Course Consultants	801 Long Island Avenue		Medford	NY	11763
7	216/456-4114	Gary Stewart	Turf & Nursery Supply, Inc.	P. O. Box 7007	3709 Columbus Rd NE	Canton	OH	44705-0007

SCHEDULER INTERNATIONAL DISTRIBUTORS

	PHONE	FN	COMPANY	ADDRESS	ADDRESS2	CITY	COUNTRY	ZIP
1	61/55-749214 (FAX)	Tom Napier		P. O. Box 501	Victoria Valley	Victoria	Australia	3294
2	805/399-9131	Doug Anderson/Robert Flores	Lake Irrigation International	P. O. Box 2248	3404 State Road	Bakersfield	CA	93303
3	209/266-8731	Larry Miller	Trans-Rim Trading Ltd.	1713 Tulare Street #221		Fresno	CA	93721
4	403/223-3591	Gordon Green	New Way Irrigation	Box 1889		Taber, Alberta	Canada	T0K2G0
5	562/552-5692(FAX)	Dr. Luis Alberto Gurovich	Servicio De Alta Tecnologia Sat	Providencia 2594 Office 309		Santiago	Chile	
7	031-71261 RAJ IN	Satish Aneja	Klron Instrument Co.	B-2, Satkar Bldg; 79-80, Nehru Place		New Delhi-110019	India	
8	39/51/453570(FAX)	Anna Tosi	Gramigna S.p.A.	Via Caselle 47		S. Lazzaro	Italy	40068
9	509/332-5951	Bob Hinrichs	American Ag International	Route 2, Box 606		Pullman	WA	99163

ST27 INTERNATIONAL DISTRIBUTORS

1	813/667-2260(FAX)	S. Suzuki	Honzawa Co. Ltd.	16-21 Koamicho Nihonbashi	Chuo-Ku	Tokyo	Japan	103

CCT SUB-DISTRIBUTORS (SCHEDULERS)

	PHONE	FN	COMPANY	ADDRESS	ADDRESS2	CITY	ST	ZIP
1	209/582-0291	Randy Davis	Helena Chemical Co.	PO Box 1263 (Zip 93230)	12218 Eleventh Ave	Hanford	CA	93232
2	209/584-4662	Krica Jensen	CCT Corporation	673 Pepper Drive, Apt. A	209/246-3680 (Car)	Hanford	CA	95230
3	916/662-5442	John Miller	Agriform Farm Supply	P. O. Box 1818		Woodland	CA	95695

Technical Bulletin

Using the ST27

The ST27 Turf monitor can be used in several ~~modes~~ ways to produce valuable management information. ~~First~~

Management ~~Objectives~~ Goal

A golf course superintendent ~~manager~~ has ~~as~~ a primary goal of producing and maintaining greens ~~tees~~ and tees which are healthy, attractive and enjoyable to ~~play~~ play golf on. This goal is achieved by managing irrigation, fertilizer, and other cultural practices. The continuing question which the manager must ask is "how is the grass performing?" Experienced managers traditionally rely on visual indications to assist them in making their management decisions. Since the main ~~purpose~~ goal of a golf course superintendent is ~~the~~ to maintain

The visual appearance of the course, ~~this is the judgement of the superintendent or that the visual appearance~~ visual assessments are essential. Many superintendents also attempt to judge the agronomic health of their turf by visual appearance. ~~this judg~~ ~~This can present Doing this creates the potential danger that problem areas will suddenly develop.~~ Unfortunately, the true health of turf is not always indicated by visual appearance. It is true that healthy greens look good. But it is also true that greens that look good today may be experiencing difficulty and may not look good tomorrow.

The difficulty of ~~an~~ accurately judging the health of an area, or the cause of a problem, solely on visual indications is the reason the ST-27 Turf Monitor was developed.

How the ST-27 Helps

Several studies have shown that when turf is healthy, ~~the~~ turf ~~surface~~ temperatures are very uniform, varying by no more than 3-4°F over an entire green. ~~As~~ When a green dries out ~~and, if~~ temperatures ~~may~~ may vary by 20°F or more. Yet in both situations, the greens look the same. If left ~~to~~ dry too ~~long~~, a green will ~~be~~ develop hard spots and brown spots. The manager may believe he has "suddenly" developed some problems when in fact, ~~not~~ the green may have been signalling for many days that it was experiencing difficulty. With the ST-27, the manager ~~can be~~ has an early-warning of developing problems, instead of waiting for the problems to progress to the point when visual symptoms develop.

clerical
trouble-shooting
management suggestion
over-irrigation

The ST-27 also helps as a trouble shooting device. One superintendent who was "absolutely positive" that a problem on his 9th green was unrelated to soil moisture because that area was irrigated was surprised to learn that the turf in that spot was 19°F hotter than the rest of the green. After a careful inspection of the plumbing system, he discovered a piece of plastic blocking the line which supplied water to that section of green. This had gone unnoticed since he irrigates at night and since all the other sprinklers were operating normally. One After discovering a hot spot on his 12th green, he found that one of his assistants had turned the sprinkler off 2 days earlier to allow some golfers players to play through -- and had forgotten to turn them

back on. ~~The Objectivity~~

The ST-27 provides answers to three major questions:

1. Are the temperatures of ~~a~~ my ~~the~~ turf surfaces uniform? If not, ~~the manager has a~~ there is a problem to solve. Uniform temperatures indicate ~~uniformity~~. optimum conditions ~~for other ways, such as irrig~~ Areas which are water-logged become too hot also, encouraging the development of weed diseases.

2. Are sprinklers operating ~~that~~ the way I think they are? The temperature patterns are an indication of the effectiveness of a sprinkler pattern.

3. Are my assistants doing something with ~~my~~ the irrigation system I'm not aware of?

Management Suggestions

Variably Cloudy Periods

~~During~~ On days where the sun is frequently covered by clouds, the ST-27 can still be used effectively. On these type of days, the superintendent would probably ignore the stress index (unless measurements were ~~made~~ only under sunny conditions anyway). The bar-graph on the back of the gun is the primary analysis tool ~~for~~ when sunlight varies. ~~The a~~ ~~to set a~~ Simply wait for the sunlight to stabilize (the cloud has either moved away from the ~~sun~~ or moved in front of it). Then note the position of the bar graph as you aim the ST-27. Does it remain steady as you walk around the green, or does it jump around (indicating a hot spot)? Even under sunny conditions this is ~~not~~ an easy to use technique. ~~which requires no further analysis.~~ ~~data collected~~

Sunny Periods

~~The Stress Index~~

The stress index is designed to operate between 11:00 a.m. and 4:00 p.m. under sunny conditions. Under these conditions, the following has been observed on bent-grass greens:

less than 0 - the best greens

~~0-4~~ 0-3 - the average good looking green

~~3-5~~ 3-5 visual changes begin occurring

above ~~5~~ 5 - severe stress, obvious visual signs ~~begin occurring~~

Because of differences in cutting ~~height~~ height, soil type, fertility practices, etc., it is possible to make the above scale shift by 1 or 2 units. We believe most ~~man~~ superintendents will want to keep the majority of their greens in the 0-1 region.

Example

The following represents a ~~hypothetical~~ scenario based on experience:

~~For~~ On a ~~daily~~ regular basis:

- measure the stress index and uniformity of your "best" tee or green.

- Compare the average stress index and uniformity ~~with~~ of ~~tees~~ and greens you're especially concerned about with "your best" area. Be sure to be as consistent as possible in sampling technique when making this comparison. Manage there other areas to duplicate the stress index and uniformity of your best area. Examine all your greens if time permits. On many courses, ~~all~~ 18 holes can be examined in an hour.

On sunny days:

- ~~To~~ Take more time to examine the ~~temperature~~ stress patterns on selected tees and greens to identify the ~~extent of~~ effectiveness of ~~to~~ irrigation applications or to evaluate the ~~scale~~ size of ~~or~~ a problem area. Visual

symptoms occur in the hardest hit areas first, but the affected area may be larger than indicated by the visual symptoms which initially appear.

Summary

The ST-27 monitors the temperature of turf and relates this temperature to "Normal Turf" via its unique index. It is the first tool to which allows a turf manager to easily determine the condition of his turf. It is easy to use, ~~provides rapid interpretat~~ providing the manager with an ability to create truly ~~uniformity in spite~~ uniform turf, both agronomically and visually.

Managing Turf with the SE 27

The following turf facts must be understood:

- Cool season and warm season grasses have different temperature tolerances.

- Optimum temperatures for root growth and shoot growth (leaves) are different. Shoot growth can proceed while root growth has stopped.

- Shoots that grow while the roots have stopped growing will deplete the carbohydrate reserves of the plant. This has important implications in the relationship between the ~~fertilizing~~ nutritional program of turf and its ability to survive in adverse conditions. The more precise the fertility program matches the physiological needs of the turf, the greater the ability of the turf to withstand heat stress if accompanied by proper irrigation.

necessarily

- Visual color is not an indication of turf health. Turf roots can be severely damaged and carbohydrate reserves exhausted, but still appear lush with proper fertilization and irrigation. Such a turf is "on the razor's edge" between looking great and collapsing and turning brown virtually overnight. The true health of turf can be judged only by examining it's root system.

- Surface temperatures can be a good indicator of the activity of a root system. To indicate turf root health, the cumulative effects of heat and moisture stress must be judged. It is the temperature pattern over time that is the most critical.

- If the temperature is too high for too long, on a single day, turf may ~~die or go dormant~~ develop problems. This is why syringing is often necessary, especially in areas that are hard to wet.

Comparison Between ~~Selected~~ Published Turf Baselines in the VPD range in which their data was collected

			VPD 2	3
Rossell (1988)	Kentucky Bluegrass	1		
Ram I	$\Delta T = 8.3 - 2.3\,VPD$ ($R^2 = 0.32$)	6.0	3.7	1.4
Sydsport	$\Delta T = 8.5 - 2.7\,VPD$ ($R^2 = 0.33$)	5.8	3.1	0.4
Baron	$\Delta T = 9.6 - 3.1\,VPD$ ($R^2 = 0.39$)	6.5	3.4	0.3
America	$\Delta T = 7.4 - 2.3\,VPD$ ($R^2 = 0.29$)	5.1	2.8	0.5
Midnight	$\Delta T = 8.1 - 2.6\,VPD$ ($R^2 = 0.33$)	5.5	2.9	0.3
		5.8 ± 0.5	3.2 ± 0.4	0.5 ± 0.3
	Perennial Ryegrass			
Prelude	$\Delta T = 7.8 - 2.7\,VPD$ ($R^2 = 0.27$)	5.1	2.4	0.6
Palmer	$\Delta T = 9.3 - 3.4\,VPD$ ($R^2 = 0.36$)	5.4	2.5	−0.9
Derby	$\Delta T = 8.6 - 2.8\,VPD$ ($R^2 = 0.26$)	5.8	3.0	0.2
Pennfine	$\Delta T = 7.3 - 2.3\,VPD$ ($R^2 = 0.19$)	5.0	2.7	0.4
Manhattan	$\Delta T = 9.3 - 3.2\,VPD$ ($R^2 = 0.36$)	6.1	2.9	−0.3
		5.5 ± 0.5	2.7 ± 0.3	0.0 ± 0.6
Carrow (1988)				
Tifway	$\Delta T = 5.74 - 1.25\,VPD$ ($R^2 = 0.25$)	4.5	3.2	1.9
Meyer Zoysiagrass	$\Delta T = 6.26 - 1.41\,VPD$ ($R^2 = 0.38$)	4.9	3.4	2.03
Common Centipede	$\Delta T = 4.69 - 0.86\,VPD$ ($R^2 = 0.16$)	3.8	2.9	2.11
		4.4 ± 0.6	3.2 ± 0.3	2.0 ± 0.1

Heat Stress

Absolute
Temp too high

Relative
too high

Moisture Stress

Absolute
O.K.

Index
too high

(Time: how many days > 95°F?)

Visual
Green/Brown & Optimal Tc, index low

Green/Brown & high Tc, index low

Green/Brown & high Tc, index high

~~Green~~

heat $
zone $
UARIA$
sun $
INDEX $

CLV 193-C

SHEET NO. _____ OF _____

FILE _____

SUBJECT _____

DATE _____

BY _____

Root growth

~~Bentgrass~~ Cool Season — stops at 90 °F

Biological death at 120 °F

Warm season stops at about 105

Biological death at ~~140~~ ~~130~~ ~~140~~ 135

Cool Season minimum = 40 °F

Warm Season minimum = 55 °F

cool season chlorophyll ↓ max at 75-85

optimum FC 75-85 F

bent. ⇒ Heat stressed at 95 °F

(darker green).

~~Heat - 3~~

~~Zone - 3~~

VARIA - 3

Std Sun - 2

Index = 4

Heat Zone	Sampling std	Sun std	Index

ST 27 Criteria

1. Stress must be indicated before the eye can see it, otherwise the ST 27 is useless. This means the instrument must say "stress" when the eyeball says it's O.K.

2. Stress is defined as a reduction in ET level which will eventually cause a color change. The length of time for a given stress level to actually cause a color change depends on:

   - how long the current stress level has existed
   - fertility regime
   - grass mixture
   - cultural practices
   - severity of the weather
   - disease / insect problems

stress decision criteria

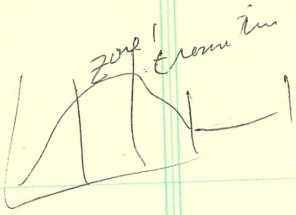
if $\overline{S.I.} > 4$, then => stress

if S.I < 4, then :

if Sun >

if Temp > 100 and cool season grass, then stress begins for some
if Temp > 115 & warm season, then Stress for some

- Genetic differences among grasses allow for different tolerances to stress (length of time to turn color)



Stress Factor #1
Optimum Temperature)

$S1 = [T_c - T_o]$

$T_o =$ ~~80~~ ~~85~~ $[60-75]$ cool season
$[75-90]$ warm season

1) Is T_c < > T_o range:

~~#~~ ~~#2~~
Cool Season

60-75 = optimum
75-90 = transition, probably OK
90-125 = slow transition to brown

Stress # 2

How long at this T_c?

Has the temp been optimum for days or week?

#3

$T_c - T_a$

if $T_c - T_a$ is negative, transpiration / evaporation is adequate

if $T_c - T_a \geq 0$, then ~~condition~~ is ~~unknown~~ model

if $(T_c - T_a) > 23$ F then stress is guaranteed.

$(T_c - T_a) \geq 0$ ~~≤ 10~~, then highly ~~unknown~~

$(T_c - T_a) \geq 10$ ≤ 23 stress is likely

#4

(Std)

If STD $> 2^\circ$C (4°F)
then stress is possible

#6

Sun Medley

heat / moisture

if Sun L 65, status is ~~no dg~~. pressure should be relieved.

#5

elevation above danger point

1) cool season D.P. = 95 °F

2) warm season = 110 °F

$SS = (T_c - D.P.)$

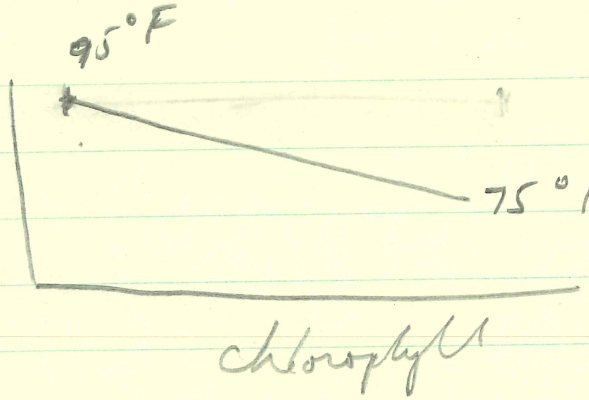
#6

If index is negative, then ignore.

Index must be positive

#6 Time

How long at a stress level?



- cool season Bentgrass
- Turf is greener at 95°F than at 75°F but has less chlorophyll.

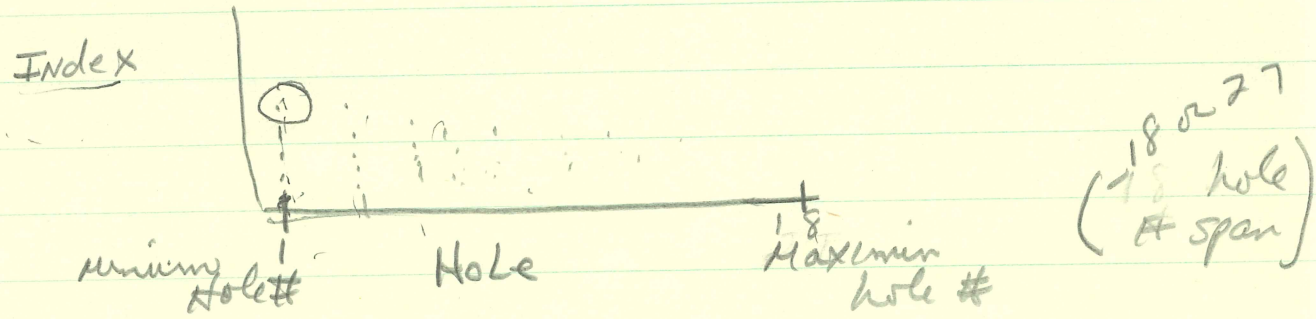
- Turfs appear darker green at soil temperatures which restrict root growth

Steve,

why don't we just delete the historical files out of the ST 27?

Also delete the automatic erasing of data at midnight

Then ~~on a daily~~ make 1 graph



put all 5 data points per hole on the 1 graph.

F
B
M

-Bronson

California ET_o (North → South)

County	City	JAN	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Santa Cruz	Watsonville	1.46	1.76	2.69	3.66	4.64	4.49	4.88	4.15	4.02	2.93	1.77	1.22
San Joaquin	Stockton	0.79	1.54	2.93	4.72	6.22	7.44	8.06	6.83	5.31	3.23	1.42	0.61
Merced	Merced	0.98	1.54	3.17	4.72	6.59	7.91	8.54	7.20	5.31	3.42	1.42	0.73
Napa	St. Helena	1.22	1.54	2.81	3.90	5.13	6.14	6.96	6.22	4.84	3.05	1.42	0.85
Sonoma	Santa Rosa	1.22	1.65	2.81	3.66	5.0	6.02	6.10	5.86	4.49	2.93	1.54	0.73
Madera	Madera	0.92	1.43	3.17	4.84	6.59	7.80	8.54	7.32	5.31	3.42	1.42	0.73
San Benito	Hollister	1.46	1.76	3.05	4.25	5.49	5.67	6.35	5.86	4.96	3.54	1.65	1.10
Monterey	Monterey	1.71	1.76	2.69	3.54	4.03	4.13	4.27	4.15	3.54	2.81	1.89	1.46
Kings	Hanford	0.85	1.54	3.42	4.96	6.59	7.68	8.30	7.20	5.43	3.42	1.42	0.73
Tulare	Visalia	0.98	1.76	3.42	5.43	6.96	8.15	8.42	7.20	5.67	3.78	1.65	0.85
Fresno	Fresno	0.85	1.65	3.30	4.84	6.71	7.80	8.42	7.08	5.20	3.17	1.42	0.61
Kern	Shafter	0.98	1.65	3.42	4.96	6.59	7.68	8.30	7.32	5.43	3.42	1.54	0.85
San Luis Obisbo	San Luis Obisbo	1.95	2.20	3.17	4.13	4.88	5.31	4.64	5.49	4.37	3.54	2.36	1.71
Santa Barbara	Santa Maria	1.83	2.20	3.17	4.02	5.00	5.08	5.13	5.13	4.49	3.54	2.36	1.71
Ventura	Oxnard	2.20	2.54	3.17	3.66	4.39	4.61	5.37	4.76	4.02	3.30	2.36	1.95
L.A.	Lancaster	2.14	2.98	4.64	5.91	8.54	9.69	10.98	9.76	7.32	4.64	2.78	1.71
L.A.	Long Beach	2.20	2.54	3.42	3.78	4.76	4.96	5.25	4.88	4.49	3.42	2.36	1.95
San Bernadino	Barstow	2.56	3.64	5.74	7.91	10.13	11.57	11.96	10.37	8.62	5.74	3.31	2.07
Orange	Santa Ana	2.20	2.65	3.66	4.49	4.64	5.43	6.22	6.10	4.72	3.66	2.48	1.95
Riverside	Palm Springs	1.95	2.87	4.88	7.20	8.30	8.50	11.59	8.30	7.20	5.86	2.72	1.71
	Riverside	2.07	2.87	4.03	4.13	6.10	7.09	7.93	7.57	6.14	4.15	2.60	1.95
San Diego	San Diego Warner Springs	2.20	2.54	3.30	3.43	4.39	4.02	4.64	4.64	3.90	3.30	2.24	1.95
Imperial	Brawley	2.81	3.75	5.86	8.03	10.37	11.46	11.72	10.01	8.39	6.22	3.54	2.07

Hyatt, Essex Room

5 Aug - 14 Sept - 1987

Clark Throssel

Range = 1 - 3 VPD

Kentucky Bluegrass

			R^2
1	Ram I	$\Delta T = 8.3 - 2.3$ VPD	0.32
2	Sydsport	$\Delta T = 8.5 - 2.7$ VPD	0.33
3	Baron	$\Delta T = 9.6 - 3.1$ VPD	0.39
4	America	$\Delta T = 7.4 - 2.3$ VPD	0.29
5	Midnight	$\Delta T = 8.1 - 2.6$ VPD	0.33

Perennial Ryegrass

			R^2
6	Prelude	$\Delta T = 7.8 - 2.7$ VPD	0.27
7	Palmer	$\Delta T = 9.3 - 3.4$ VPD	0.36
8	Derby	ΔT ~~8.6~~ $= 8.6 - 2.8$ VPD	0.26
9	Pennfine	$\Delta T = 7.3 - 2.3$ VPD	0.19
10	Manhattan II	$\Delta T = 9.3 - 3.2$ VPD	0.36

* Conclusions

1. Baselines Vary among varieties within a species
2. At a VPD of < 2.5 KPa There is a considerable variability in canopy Temp

3. CWSI may have limited utility for irrigation Scheduling at VPD of < 2.5 KPa

11 Standardbred Oil = 7.0 - 1.9 VPD

Carrow

Range = 1-3 VPD

12 Tifway ~~ΔT~~ $\Delta T = 5.74 - 1.25\ VPD$ $r = -.50$ $N = 37$

13 Meyer Zoysiagrass $\Delta T = 6.26 - 1.41\ VPD$ $r = -.55$ $N = 39$

14 Common Centipede $\Delta T = 4.69 - 0.86\ VPD$ $r = -0.40$ $N = 38$

Conclusion: $\Sigma (T_C - T_A) = SDD$ is better than CWSI in humid areas

R_N = 400 to 699 W/m²

Range = 7-5 VPD

Horst

Common Bermudagrass

15 1986 $\Delta T = 7.82 - 1.96$ VPD $r^2 = 0.54$ $N = 299$

16 1987 $\Delta T = 8.84 - 2.60$ VPD $r^2 = 0.53$ $N = 333$

Mowing height = 2.5 cm

Texoka Buffalograss

1986 $\Delta T = 9.27 - 2.11$ VPD $R^2 = 0.70$ $N = 299$

1987 $\Delta T = 9.40 - 2.74$ VPD $R^2 = 0.54$ $N = 305$

mowing ht = 5.0 cm

~~Raleigh~~ Raleigh St. Augustine

17 1986 $\Delta T = 7.36 - 2.03$ VPD $r^2 = 0.65$ $N = 299$

18 1987 $\Delta T = 6.26 - 2.19$ VPD $r^2 = 0.42$ $N = 313$

mowing ht = 5.0 cm

Falcon Tall Fescue - mowing ht = 5.0 cm

19 1986 $\Delta T = 6.35 - 1.97$ VPD $R^2 = 0.50$ $N = 299$

20 1987 $\Delta T = 6.50 - 2.50$ VPD $R^2 = 0.37$ $N = 327$

~~Conclusion~~ Results

1. Relationships of VPD vs $T_C - T_A$ varied as the meteorological conditions varied
2. Average R_N was less in 1987, Average VPD was less in 1987
3. VPD versus ΔT was more negative in 1987 (measurement Technique)
4. R^2 higher in 1986 than in 1987
5. Canopy Temp's more responsive to VPD in 1986 than in 1987.

Horst

Conclusions

1. Baseline relationships for ΔT should not be extrapolated beyond the region of data acquisition

2. Baseline relationships should not be extrapolated across different turfgrass species

3. Acquisition of data for baseline needs to be over the entire expected VPD range

4. Additional factors such as R_N, and windspeed need to be considered in the VPD x ΔT baseline for useful CWSI calculation.

ST27™ OWNER'S MANUAL SUPPLEMENT

RESEARCH AND CONSULTANT MODEL

OVERVIEW OF THE R & D SOFTWARE FOR THE ST27™ TURF MONITOR

I. Turn the unit on. There are three options: HELP, PRINT, ENTER.

HELP - Provides a description of EACH key function.

PRINT - Selects the option to Print data, reconfigure the RS-232 parameters, or reset optional program features.

ENTER - Begin execution of the Main Program.

II. Key Descriptions

ENTER - Runs program, enter selected values of hole, area, date, or time.

PRINT - Selects the option to print data, reconfigure the RS-232 parameters, or reset optional program features.

UP AND DOWN ARROWS - Selects a value of hole, area, date or time, or scroll to next screen when indicated.

CALC - The first push of CALC produces sample averages, after at least 1 data point is taken. The second push of CALC (after averages are computed) automatically increments the area number by 1 and re-starts the data collection screen. If CALC is pressed immediately after the machine is turned on, the battery voltage level will be shown.

HELP - Help is used to provide information at various points in the program.

III. Print Option

The Print option can only be accessed immediately after the machine is turned on. The Print options are: CALC, ENTER, PRINT.

A. CALC - Configurations Menu. Use the Up and Down Arrow keys and the ENTER key to select:

Baud Rate (50, 75, 150, 300, 600, 1200, 1800, or 2400)
Char Size (5, 6, 7 or 8)
Stop Bits (1 or 2)
Parity (none, odd, even, mark, or space)
Xon/Xoff (enable/disable) -- allows the ST27™ to respond to transmit/ no transmit commands from an external device. Usually Xon/Xoff is used in the Disable mode.

B. ENTER - Flags Selection. Use the up and down arrows and the ENTER key to select:

SUN LOW ERR - (Disable or Enable). When this option is enabled, the ST27™ rejects any samples where the indicated sun light reading is below 65%. When this option is disabled, the ST27™ will take readings at all times.

DATA LOGGER - When this feature is enabled, ALL the samples collected will be transmitted through the RS-232 port for external recording by another RS-232 device. The automatic 10 minute time-out feature is disabled when this feature is enabled.

DISPLAY - Select ^{O}C or ^{O}F for the indicated temperature.

PRINT - Begins transmitting the memory file to a printer or computer. The data will not transmit if a computer or printer is not hooked up. To end a print sequence when a printer or computer is not looked up, press ENTER. Note: This is the only pathway to the ERASE MEMORY option. After the Print sequence is finished or aborted, the erase memory option will appear.

IV. Main Program

Turn machine on. Press ENTER.

1. Select area number: The area number ranges from 1 to 240. Select an area number by using the Up and Down arrows and the ENTER key. The DEL (delete) key can be used to correct mistakes. Note that each position of the area number is selectable.

2. Select Area: Your ST27™ is programmed with 5 areas for each hole : Tee, Green, Fairway, Rough and Other.

3. Set Time: To reset the Date and time, press CALC and use the ENTER and Up and Down arrows.

4. Review Field History: Press CALC. This shows the last set of data taken on this area. Field data is retained in memory until you choose to erase the memory.

5. Begin Sampling: Press ENTER. If the message, "Sample this area again today?" appears, it means you must now decide whether to keep or delete the stored data for a field. This message will appear whenever an area has stored data. To avoid seeing this message when collecting data, it is necessary to clear the memory first. See the Print option for a description of how to do this.

V. Data Collection

A 94-second countdown will always apear whenever it has been more than 10 minutes since data was last taken. The sensor gun should not be in the holster during the 94 second countdown. This will assist the air temperature and humidity sensors in equilibrating.

The Data Screen

Before the first data point is taken, the turf temperature and air temperature readings are "Alive", meaning they will display the real time readings of these sensors. In this mode, the ST27™ can be used as a normal infrared thermometer to scan the temperature of a surface (or observe the temperature the ambient air). Note, this mode will work for 10 minutes. If no data are taken, the unit will shut itself off.

To collect data, press the trigger or the ENTER button. Data are sampled in bursts at the rate of 4 samples per second. The data screen displays the last sample in a burst. After the data are collected (maximum of 55 samples per burst up to a total of 999 samples), the message "Calculating" appears. The more samples in a burst, the longer the calculating delay.

The data screen contains the following information:

SAMPLE - The total number of samples (up to 999).

STD - The standard deviation of turf temperature (^{o}C or ^{o})F

CROP - Crop Temperature (^{o}C or ^{o}F). The temperature displayed assumes an emissivity of 1.0.

RH - Relative Humidity (%)

AIR - Air Temperature (^{o}C or ^{o}F)

SUN - Approximates the value of direct beam solar radiation in mW/cm^{2}. The Sun reading saturates at a value of 100. This reading can also be interpreted as the percent of direct beam sunlight available.

INDEX - The index value. The index is based on work conducted in California, Kansas, Indiana, Georgia and Florida. The equations used and the calculation procedures are proprietary. They are based on the Idso CWSI concept. Modifications to Idso's procedure have been made to allow for improved response at low VPD values.

VPD - The VPD value (kPa). All values displayed are the last sample value in a burst. This holds a sample on the screen for recording by hand or for in-field analysis.

When you have collected all the samples for a given area, press CALC to see the average of all parameters collected.

At this point, you have two options.

1) Press CALC again. This automatically increments the area number. The crop will be whatever this area has been previously set to. It is not possible to change the crop using this mode. The sensor gun does not turn off; you are ready to start another sample sequence: PULL the trigger to sample; press CALC to average; press CALC to start a new area. The data averages are automatically stored. All data points sampled can be captured by attaching an external RS-232 device (such as a polycorder) and enabling the data logging provision. Although data capture is very rapid, you will note that data calculation and transmition seem slow. This is caused by the large number of calculations performed on the data.

2) Press ENTER. This returns you to the main menu. You can select any area or crop combination. The sensor gun should turn off when you are in this screen.

VI. Operating Suggestions

1. Keep the sensor gun out of the holster at all times during use. The holster has its own microclimate.

2. Keep the sun from directly shining on the right side of the sensor gun. It is possible for sunlight to shine directly on the air sensor, producing an error.

3. Minimize the exposure of the gun to large step-changes in ambient conditions. If the gun case is more than 15^{o}F hotter or colder than the ambient, the aspiration fan may not be able to remove all the bias caused by heat transfer between the case and the sensors. The closer the gun case remains to ambient temperature, the better.

4. Do not point the sensor gun at the sun. This can damage the IR detector (it overloads the detector). Remember, the sun has an apparent temperature of 6035^{o}C (11,000^{o}F). The ST27^{TM} IRT detector saturates when a target is plus or minus 150^{o}C (270^{o}F) from ambient.

5. Aim the sensor gun properly. The equations for calculating your spot size are simple. Use them to make sure you are not seeing sky. NOTE: when the sky near the horizon is seen, the indicated reading will be near ambient. When the sky several degrees above the horizon is seen, the indicated IR will be very cold, depending on the degree of cloud cover and the moisture content of the air.

6. Do not get moisture in the nose of the sensor gun. Some electrical circuitry is exposed and could be damaged.

7. Clean the lens of the IRT with ethanol that does not have denaturing additives (the additives leave a residue), or use a camel's hair brush (from an art or photography store), or with a damp cloth and a mild detergent (use distilled water).

VII. Sensors

Infrared Thermometer - Operates in the 8-14 um interval with an 8 degree total FOV. Designed and manufactured by Standard Oil Engineered Materials Company This infrared thermometer is a D.C. infrared thermometer. It does not have a mechanical chopper to compensate for changes in the temperature of the detector. Compensation is achieved by, 1) software analysis of the detector and, 2) internal thermal design. The IRT has been designed to operate within specifications as long as the internal temperature of the IRT is not changing more rapidly than $1^{o}C$ per minute. This condition will not be exceeded unless the instrument is exposed to a step-change of $20^{o}C$ ($36^{o}F$) in ambient conditions. When a step-change of this magnitude occurs, a waiting period of up to 20 minutes may be required for the instrument to operate within specifications.

Air Sensor - A thermister accurate to $0.1^{o}C$. Thermal interferance from the case reduces this accuracy to $0.2^{o}C$. IRT Case temperature should be within 15^{o} of ambient to minimize thermal interferance.

Relative Humidity Sensor - Resistance change through a bulk silicon polymer. A thermosetting resin is used which provides excellent stability. The silicon polymer protects the sensing elements from direct contact with most pollutants, including dirt. This polymer, while protecting the sensor and preserving its calibration, reduces its time response. It takes 3-5 minutes for this sensor to equilibrate to large step-changes in humidity (e.g., 20% to 60%). This should pose no problem for normal field use.

Sun-light - Two photo-diodes, wired in parallel, off-set an angle of 120°. The diode outputs remain approximately constant as the solar elevation angle changes, under sunny conditions. The output of the diodes responds to changes in solar intensity caused by clouds. In the current software, the sun reading is not used in the index calculation. It is currently used as a data-quality feature. If the sun reading is below 65, readings will be automatically rejected. This feature can be disabled.

APPENDIX I

Calculating the spot size of an IRT

F_2 = (FOV/2) The IRT in the ST27™ has an 8^{o} FOV at the extremes, about 6^{o} FOV at the half power points.

H = Height of IRT above the turf canopy

D = Horizontal distance from the IRT to the target.

S = Short axis of the spot size. The distance from the target back toward the observer to the edge of the FOV.

L = Long axis of the spot size. The distance from the target away from the observer to the edge of the FOV.

K = Indicator of whether or not sky is seen. If K is positive, no sky is seen. If K is negative, sky is seen. If K is between -1 and 0, the error is probably small. For calculation purposes, if K is less than 0.001, set K=0.001, or the trigonometric functions used will blow up. If K is less than -1, the IRT readings will be seriously biased by sky temperature.

W = Maximum width of the spot size

Calculations

All trig functions are in degrees. The example given is for a FOV of 6^{o}, height of 4 ft. and target distance of 25 ft.

*F_2 = FOV/2

1) $Z = (D^2 + H^2)^{1/2} = (16 + 625)^{1/2} = 25.3$

2) $G = \text{Sin}^{-1}\left(\frac{D}{Z}\right) - F_2 = \text{Sin}^{-1}\left(\frac{25}{25.318}\right) - 3 = 77.9$

3) $C = 90 - F_2 - G = 9.09$

4) $S = \frac{Z \sin(F_2)}{\sin(G + 90)} = 6.3$ ft.

5) $K = 90 - G - 2F_2$, If $K < 0.001$, then $K = 0.001$
If $K < 0$, Then "sky is seen"
If $K < -1$, Then "Do not use at this angle"
For this example, K = 6.1

6) $L = \frac{Z \text{ Sin } (F_2)}{\text{Sin } (K)} = 12.5$ ft.

7) T = TOTAL length of spot size = L + S
= 18.8

8) $W = 2 Z \tan (F_2) = 2.6$ ft.

9) Total area viewed = 3.14159 TW/4
= 39.2 $ft.^2$

APPENDIX II

Transmitting data to a computer.

the cable supplied with the ST27™ has the following configuration:

Pin #	Function
1	Case Ground
2	Receive
3	Transmit
7	Signal Ground
8	DTR Out
20	DSR In

To connect the ST27™ to most serial printers, the cable supplied with the ST27™ should be adequate.

To transmit ST27™ memory files or data to an IBM P.C., it is necessary to make a straight through cable with pins 6 and 8 jumpered.

To transmit ST27™ memory files or data to a polycorder, an adapter is needed.

ST27 Pins	Polycorder Pins
1, 7	7
2	2
3	3
6, 8	No Connection
20	25

Software

The following commands will allow you to transfer your data to the IBM (The ST27™ must be attached to a COM port).

IBM

1) Mode COM X: 12, N, 8, 2 (X is the Com port number)

2) Copy COMX < File Name > Name your file

3) Configure the ST27™ as follows (using the PRINT option):

   Baud 1200
   Char. Size 8
   Stop Bits 2
   Parity None
   Xon/Xoff Disabled
   Sun Low Disabled or enabled

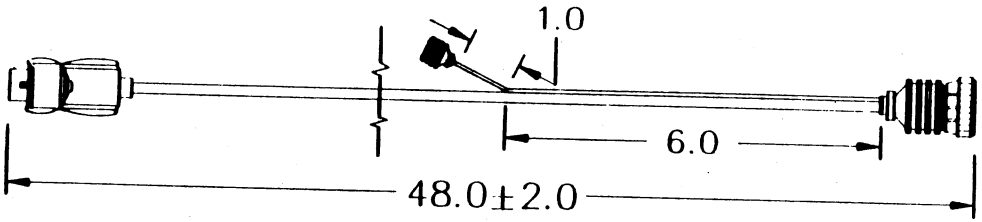
4) Execute the PRINT option.

5) All data (including headers will be transferred). A CTRL-Z is sent at the end of file to return the IBM to normal operation.

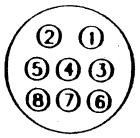
Polycorder

Software for down-loading the ST27™ to a Polycorder is being developed.

DIMS. IN INCHES



PIN CONTACTS



WIRING SCHEDULE

SIGNAL DESCRIPTION	SIGNAL NAME	8 PIN CIRC. CONN.	COLOR	MALE DB25	CABLE PORT
CASE GROUND	RS_GND	5	BLUE	1	NC
DATA INTO COMPUTER	RS_RXD ◄—	3	BRN	2	NC
DATA FROM COMPUTER	RS_TXD —►	6	GREEN	3	NC
SIGNAL GROUND	RS_GND	5	BLUE	7	NC
DTR OUT OF COMPUTER	RS_DTR —►	7	ORN	8,6	NC
RING INTO COMPUTER	RS_RI ◄—	8		NC	
CARRIER INTO COMP.	RS_CD ◄—	1	YEL	20	NC
BAT. +	BAT. +	2	RED	NC	
BAT GND.	BAT. GND.	4	BLK	NC	

JUMPER 6&8 ON DB25

PRINTER CABLE

figure -1-

trometer measurements of plant color of common Bermuda, Tall fescue, St. Augustine, and Buffalo grass. In short, the Monitor gives you the accuracy of laboratory technology in a practical, portable package.

Soil Moisture

In a separate study conducted at the University of Florida's Fort Lauderdale Experiment Station, ST27 Turf Monitor readings consistently reflected actual soil moisture conditions under St. Augustine grass.

Upgrade Or Go It Alone

The ST27 Turf Monitor is a low-cost tool that, alone, gives a manager the power to structure a comprehensive irrigation program.

If, however, you already have an automated irrigation control system, you can still benefit by the addition of the ST27 to your arsenal. The ST27 complements even the most sophisticated system by providing instant, accurate data on turf conditions and allowing you to adjust your irrigation program accordingly.

If turf is part of your business, then the ST27 Turf Monitor just makes sense — any way you look at it.

For more information on the ST27 Turf Monitor, consult your local representative or contact Standard Oil Engineered Materials, P.O. Box 391316, 6180 Cochran Road, Solon, OH 44139. Phone 216 349-6881. Telefax 216 349-4047.

The ST27 Turf Monitor: Powerful and Well Connected

With the ST27 Turf Monitor, you can communicate with other computers and printers, transferring or printing the information you gather. The RS 232 serial port connector and cable allow you to plug into a wide variety of PCs and printers:

- Compile a permanent, ongoing, hole-by-hole record of your irrigation program and its effectiveness by printing daily sampling results and three-day historical records.
- Develop irrigation models and generate custom programs geared to your course and your needs.

ST27™ Turf Monitor

STANDARD OIL
ENGINEERED MATERIALS

ST27™ Turf Monitor is a trademark of the Kennecott Corp.

The information, recommendations, and opinions set forth herein are offered solely for your consideration, inquiry, and verification and are not, in part or total, to be construed as constituting a warranty or representation for which we assume legal responsibility. Nothing contained herein is to be interpreted as authorization to practice a patented invention without a license.

Form 15,053
New: 7/87
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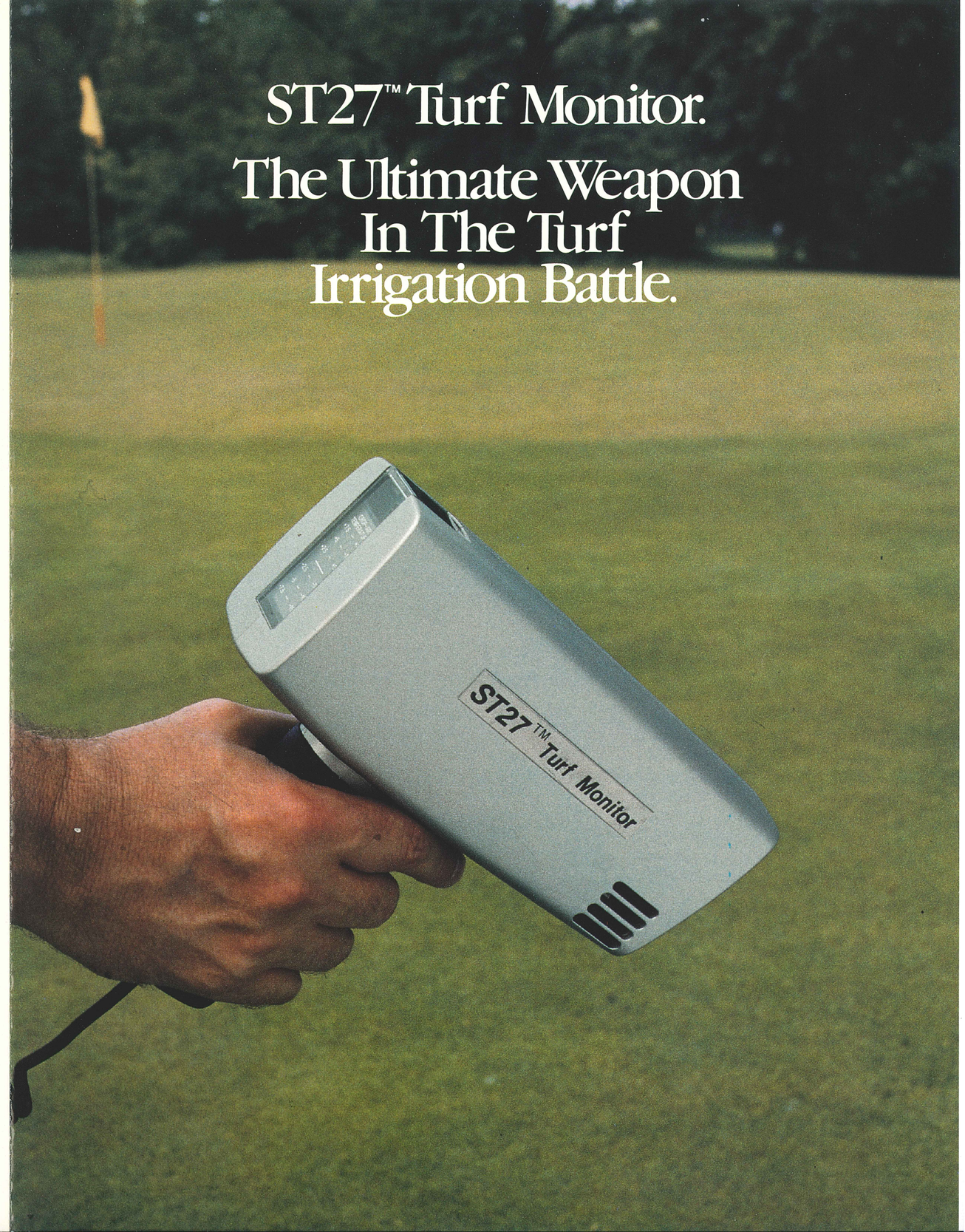
ST27™ Turf Monitor. The Ultimate Weapon In The Turf Irrigation Battle.



The ST27™ Turf Monitor. The Future of Turf Irrigation Management Has Arrived.

The ST27™ Turf Monitor is an entirely new concept in irrigation management. For the first time, a golf course manager has a tool that allows him to:

- Make watering decisions based on actual needs.
- Cut watering costs and still maintain top turf quality.
- Spot turf stress before it can be seen with the eye.

Here, in one handy instrument, is all the information you'll ever need for a superior irrigation program.

A Breakthrough in Turf Management.

The ST27 Turf Monitor combines the latest in turf irrigation, agronomics, and state-of-the-art electronics. It represents a dramatic advance over conventional equipment that is limited to measuring soil moisture. The Monitor attacks the problem directly, measuring the actual condition of the plant, and its response to available soil moisture:

- The Monitor measures current turf conditions, charts past conditions, and allows you to predict future requirements.
- The Monitor is light, battery-powered and portable.
- The Monitor is easy to learn and easy to use — no special training or computer knowledge is required.

Shoot Down Irrigation Problems

Point the ST27 Turf Monitor Sensor Gun at a green or fairway, pull the trigger, and the Gun reads the "vital signs" of turf conditions — air temperature, humidity, solar radiation, and canopy temperature. Instantly, the information is fed to the ST27's side-pack microcomputer where it is interpreted and recorded, giving an accurate reading of the turf's physiological state.

Repeat this again on a daily basis, and the ST27 automatically compiles an ongoing record of the changing turf conditions for that location. And a single ST27 Turf Monitor has the capacity to track up to 135 areas on your course that you wish to monitor — tees, greens, fairways, rough, or any other area. That's the equivalent of 27 complete holes.

The Best Turf Manager Can Become Even Better

The ST27 Turf Monitor offers nothing less than a revolutionary change in your approach to turf management. Now you can go on the offensive, pinpointing your exact irrigation needs. No more pouring on the water just to be on the safe side.

- Analyze and customize your entire course, adjusting irrigation for seasonal changes.
- Analyze and adjust individual areas for evenness of application.
- Fine-tune individual controllers or timers to compensate for problem areas.

BATTERY BACKED-UP INTERNAL MEMORY. Automatically stores and updates three full days of information on 135 turf areas.

RS 232 SERIAL PORT. Download information for permanent records. Communicate with a printer or PC.

LCD DISPLAY. See on-the-spot results of your sampling. Separate screens lead you through sampling, charting, and analyzing results. Able to be read in the brightest sunlight.

DURABLE CONSTRUCTION. Lightweight (8 lbs.) and compact. Engineered to meet your demands, and built to perform in the field.

64K MICROPROCESSOR. Organizes and records readings gathered by Sensor Gun. Charts ongoing turf performance for up to 135 separate turf areas.

SENSOR GUN. 4 separate sensors in one integrated package: Infrared thermometer records turf canopy temperatures. Solar radiation sensor gauges turf's exposure to sunlight. Relative humidity and ambient temperature sensors provide information on turf environment.

HOT SPOT DETECTOR. Infrared thermometer in the nose of the Sensor Gun detects turf hot spots. Useful in checking for insect damage and disease.

Depend On It

The ST27 Turf Monitor is a product of Standard Oil Engineered Materials, a unit of the Standard Oil Company. It has been extensively field tested for durability and accuracy in the lab and on golf courses.

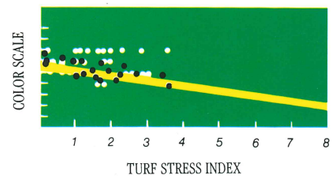
Both university studies and golf course performance show that ST27 Turf Monitor turf stress measurements provide accurate quantitative estimates of turf quality and soil moisture contents:

Quality of Turfgrass

The quality of turfgrass is generally determined by visual rating scores, but visual ratings depend on the opinion of the evaluator. Research at Texas A&M University has demonstrated that even experienced turf professionals often strongly disagree on the quality of a given turf area.

However, turf color and quality can be measured with consistent accuracy with a spectrometer. Unfortunately, spectrographic equipment is not practical for routine use outside of the laboratory.

The ST27 Turf Monitor bridges this gap. The Texas A&M study found that the stress index provided by ST27 Turf Monitor correlates closely with spec-



Above: The visual scoring of the quality of Bermuda grass (white dots) compared with Spectrometer readings (black dots) and the turf stress index as calculated by the ST27 Turf Monitor (yellow line)

Turf Temperature Facts

A Special Report for the ST27

by
Bronson Gardner

. Any biological process, disease or insect has an optimum temperature. As temperatures increase or decrease from this optimum, growth is proportionally decreased until it totally ceases. Further increases or decreases in temperature result in biological death. There is very little biological activity above tempeatures of 125 F or below 32 F. Turfgrass growth is usually confined to temperatures of 40 F to 105 F. Cool season grasses function best between 60 and 75 F. Warm season grasses function best between 80 and 95 F (root zone temperature).

. Surface temperatures above 90 F can cause a restriction in Kentucky bluegrass root and rhizome growth, even though the remainder of the root zone may be cooler. Bentgrass root growth ceases above soil temperatures of 90 F.

. The average daily soil temperature at 6 inches is highly correlated with root growth of creeping bentgrass and is the best predictor of seasonal variations in rooting.

. Turf growing in its optimum temperature range have an increased nutrient, water and mowing requirement.

.Maximum turf temperatures occur about 2 hours after solar noon.

. Root temperatures at 6 inches depth are about 15 F cooler than surface temperatures on bentgrass cut at 0.25 inches on a clear day in July or August. The differential will be less on long turf (12-24 inches).

. Temperatures in the turfgrass environment may be much less or much more than standard air temperature measurements, depending on time of day and type of day.

. Wind reduces the vertical air temperature gradients.

. Vertical air temperature gradients (between the surface and 3 ft above the surface) may range from 12 F when the grass is cut at 0.25 inches to 20 F when the grass is cut at 24 inches.

. Shaded turf may be up 20 F cooler than sunlit turf.

. The boundary layer of turf is about 0.5 inches above the surace under calm conditions.

. The temperature of cool season grasses is more sensitive to windspeed variations than warm season grasses.

. Cool night-time temperatures help stimulate improved color.

. Night-time temperatures affect the maximum day-time temperature grasses can tolerate.

. The optimum temperatures for photosynthesis are higher than the optimum temperatures for shoot and root growth.

. Carbohydrate reserves tend to accumulate if turf temperature is higher or lower than the optimum for root growth. Carboydrate reserves tend to decreases after a mowing.

. The chlorophyll content of creeping bentgrass is maximum between 75 and 85 F. The visual color of bentgrass becomes darker at 95 F, but the chlorphyll content is actually lower. Turfs appear darker green at soil temperatures which restrict root growth.

. Heat stress occurs when turf is exposed to temperatures which limit root growth. Heat stress weakens turf (although it may not change its color) so that it is more easily killed or injured by wear, water stress or disease. Heat stress usually occurs at the same time as water stress, but can occur separately. Heat stress problems are more common among the cool season than the warm season turfgrasses.

. Heat stress effects which cause browning after an extended period of time (in order):
    . increase in the rate at which roots mature.
    . blockage of new root initiation.
    . death of the root system, followed by browing of the roots.
    . decline in shoot growth, along with reductions in leaf length, width, area and the rate of new leaf appearance.
    . leaves become dark green (looking great).
    . decrease in turf density.
    . leaves die and become brown.

. Moisuture stress effects can cause rapid browning :
  . cool season grasses are the most sensitive.
  . soil temperatures are more important than air temperatures.
  . The temperature of the surface soil layer controls the response of the plant (temperatures at other layers don't matter if the surface is too hot).
  . Low density turf is more subject to higher surface soil temperatures than dense turfs. Lethal temperatures may occur at the soil surface of low density turf. Thus, the "straightdown" view is the most representative IRT temperature for judging the temperature of the roots.
  . damage occurs as follows :
    1. protoplasm granulates
    2. protoplasm coagulates — color changes/wilt
    3. cell walls breakdown
    4. cell walls collapse
    5. the second youngest leaf elongates to normal length, but the blade turns brown , starting at the base, toward the tip.
    6. the fourth youngest leaves repeat this pattern..
    7. large scale brown-out.

. Heat Hardiness

The ability of a given turf at a given location to withstand heat depends on :
  . environmental conditions
  . cultural practices
  . age
  . type of turf.

Shade (reduced light) reduced hardiness. Exposure to low tempeatures or moisture stress increases heat hardiness. Turf grown on wet soils or constantly irrigated are less heat hardy that when grown under water stress.

Heat hardiness is reduced by excessive nitrogen levels. It is critical to have the proper balance of phosphorous and potassium to achieve maximum heat hardiness. Heat hardiness is reduced as the soil PH is reduced.

Heat hardiness is reduced at short cutting heights. Younger leaves are more heat tolerant than older leaves.

Direct high temperature kill of cool season turfgrass occurs at tissure temperatures of 100 to 130 F. For example, annual bluegrass is killed by a 2 hour exposure to a tissue temperature of 108 F and 100 % relative humidity. The actual lethal temperature varies with the duration of the exposure and the hardiness of the tissue. The longer the exposure period, the lower the lethal temperature.

Dormancy. Some "browning" is simply a grass which has gone into dormancy as a result of high soil temperatures. For example, Poa scabrella will go dormant , even with adequate moisture, in the summer. Dormancy is broken by exposure to moderate temperatures and waater.

Cultural practices which protect against heat/drought damage:

. irrigation (but not to excess)
. the use of heat tolerant species and cultivars
. positioning trees and bushes so as not to prevent air movement .
. raising the cutting height of closely mowed turf.
. syringing
. drainage
. dethatching
. reducing traffic
. coring
. top dressing

THE INTERACTION OF TEMPERATURE AND MOISTURE IS SO DYNAMIC THAT IT IS DIFFICULT, IF NOT IMPOSSIBLE, TO SEPARATE INDIVIDUAL EFFECTS. If a turf gets too hot, for too long, damage will occur, whether the temperature is caused by insufficient moisture, too much moisture or excessively hot air temperatures.

Diseases:
The occurence and severity of disease is influenced by temperature. Frequently, the degree of disease injury is more severe at temperatures above or below the optimum for growth of the turfgrass. Turf may have adequate moisture and exist at an optimum temperature but be attacked by a disease.

Slopes :
Turf which is grown on uneven soil (such as many undulating greens) will have significant differences in solar radiation reception on various parts of the turf. This means that some portions of the turf will seldom be in danger of heat stress and other portions may be in continuous danger. If the slope is too severe away from the sun, lack of sunlight may also threaten turf survival (grass stays well below the optimum temperature).

Mowing : Improper mowing may cause scalping, which then creates a brown spot. Increasing the frequency of mowing will increase the density and fineness of turf.

Nutrition : Adequately irrigated and fertilized turf may not have an optimum color if iron is deficient. Excess micro-nutrient applications can be toxic to turf, resulting in damage (color changes or hotter temperatures). The nutrional program should be co-ordinated with disease and stress factors.

Irrigation. Frequent irrigation is detrimental to turf. High disease incidence, reduced wear tolerance, low vigor and high suseptibility to water stress can result. Reducing irrigation frequency without inducing water stress will improve the turf.

WARNING : Free standing water can only be evaporated so fast. The remainder absorbs solar radiation and heats up. The result can be lethal temperatures (high temperatures combined with very high humidities). One cause of brown areas is scalding.

Irrigation uniformity is another factor to consider. It is possible to "irrigate" a green but have spots which receive very little water due to improper adjustments of pressure or sprinklers. The likelihood of this happening is great since most irrigations are conducted at night and the distribution patterns are hard to see. The superintendent basically can tell only if the system is "on" or "off".

Water quality is critical. Salt injury (especially on Kentucky bluegrass and bentgrass) can damage roots and raise the temperature of visually good looking turf.

Daily irrigation of greens creates the following cycle:
. the soil is more susceptible to compaction
. increased compaction restricts root growth.
. reduced rooting increases the wilting tendency
. more frequent irrigation is required.

Chemicals.
Pesticides and insecticides have the potential to permanently damage turf. They will commonly cause a temporary increase in turf temperatures. This increase should not be to great or too long lasting. Application of too much material or inadequate "watering in" may cause damage.

Nematodes: Heavily invested turf does not respond normally to fertilizer and water. This turf can be expected to be hot (high stress levels) in spite of adquate moisture. The roots may be stunted or deformed in other ways. The tops may appear normal.

Grubs : Grubs damage the root systgem. The turf can be hot and appear normal.

Billbugs : Damaged plants turn brown. The turf can be cool and appear brown. Primarily a Kentucky bluegrass bug.

Webworms : These feed on the shoots. Turf will be hot, despite water being adquate. Substantial losses of turf can result.

Ground Pearls : These feed on the roots of warm-season turf grasses. Affected areas appear chlorotic or brown, but should have a cool temperature.

Cinchbugs : infected areas become chlorotic and die under hot, dry conditions. Shaded areas stay green, while sunny areas become brown.

Aphids : turf turns yellow, then orange, then brown. Most damage is during the summer months.

Frit flies : the larvae feed on the base of the plant during hot, dry weather, especially on bentgrass and bluegrass. Their presence can be determined by placing a piece of white paper on a suspected trouble area. They will be attracted within a few minutes.

Mites : these cause blotching or spotting, chlorosis and finally death of the leaves. Plants should be hot inspite of adquate water.

Ants : their subsurface escavation activities result in desiccation of turf roots.

INTERPRETING THE ST27 INDEX

The ST27 index has a normal range of 0-10. It is possible for readings to be higher or lower than these limits. The ST27 Index is a powerful tool, but as with any new tool, it must be understood in order to be used properly.

The ST27 index indicates the relative value of turf canopy temperature when compared to a dense, non-stressed turf. Several factors influence the ST27 index value:

a. stress status of the turf
b. turf type (cool season or warm season)
c. mowing height
d. viewing angle of the ST27 sensor gun

COOL SEASON OR WARM SEASON GRASS

The University of Georgia and Texas A & M have shown that there are no significant differences in the ST27 index for Bermuda, Centipede, St. Augustine or Centipede (warm season) turf species.

Tall Fescue (a cool season grass) was generally about $4^{o}F$ cooler than the warm season grasses. This translates into an ST27 index difference of about 1.0. Under well irrigated conditions, cool season grasses can be expected to have an index value about 1.0 lower than warm season grasses.

STRESS EFFECTS

Warm season grasses tend to be more drought tolerant than cool season species. As drought stress increases, ambient conditions tend to be hotter and drier. The physiological differences between warm and cool season grasses are reflected by the behavior of the ST27 index. The ability of warm season grasses to withstand drought translates into higher index values for warm season grass than cool season grasses at similar soil moisture values. It can be expected that when cool season and warm season grasses have similar index values then soil moisture levels under the two grasses will be different. Under drought conditions, cool season grasses can be expected to reach high index levels faster than the warm season grasses, since they are less able to tolerate these conditions.

MOWING HEIGHT

Mowing height has a minor effect on the ST27 unless the differences in cutting height are extreme, such as the difference in mowing heights between greens, fairways, and rough. Greens tend to have index values slightly higher (about 1 stress unit) than fairways. Rough may be 0.5 to 1 stress unit cooler than fairways.

VIEWING ANGLE EFFECTS

The angle at which you aim the ST27 sensor gun will significantly influence the index values recorded. The key here is consistency. There is useful information available from all viewing angles. Using viewing angle to your advantage is illustrated by the following data, which compares index readings from the ST27 when aimed at the same spots from shoulder height (4 feet) at distances of 30 ft., 6 ft., and 1 ft.

Table 1. Comparison of ST27 readings at the same spot from distances of 30, 6 and 1 ft. for four turf conditions. The turf type was Kentucky Bluegrass.

		Distance to Target Area		
	Turf Condition	30 Ft. 10-20 Degree (Grazing Angle)	6 Ft. (35-45 Degree Angle)	1 Ft. (75-90 Degree Vertical Angle)
1)	Thin population, high thatch level, poor quality, non-stressed, 1" high	1.6	4.3	8.1
2)	Dense population, medium thatch level, good quality, non-stressed, 1" high	0.2	1.0	2.7
3)	Dense population, low thatch level, good quality, non-stressed, 1" high	-0.5	0.2	1.1
4)	Dense population, low thatch, weedy, non-stressed, 12" high	-0.6	-0.3	0.0

These results demonstrate the importance of being consistent with your aiming technique. At grazing angles, the thatch layer is not seen, hence the ST27 is a measure of the condition of only the existing turf. Thinly populated (but non-stressed) turf should have index levels of 2 or less. Dense populations of turf will also have low index readings at grazing angles. Dense populations of turf will also have low index numbers at low grazing angles.

As the viewing angle becomes steeper, more thatch (or soil) will be seen by the ST27 sensor. The index given will be the combined effect of turf and thatch and soil. The denser and more healthy the turf, the smaller the difference between index readings at grazing angles and other viewing angles.

Many greens are being maintained at very low cutting heights, with a top dressing of sand. Greens maintained with this type of treatment can still be monitored with the ST27. The combined effect of very low mowing heights and sand will be to offset the index by 1 or 2 stress units. For non-stressed conditions, there is a repeatable index range. As this type of area becomes dry, the index should increase rapidly. The previous illustration given on viewing angle also applies.

To some extent, it will be necessary to do some checking to determine exactly which index number you feel most comfortable with. The following are good guidelines under normal conditions:

0 or less	well watered
0 - 2	safe zone
2 - 3	marginal zone
3 - 4	critical zone
4 - 7	wilting potential
7 - 10	danger zone

BENEFITS OF THE ST-27 TURF MONITOR

1. Avoiding over-irrigation. By systematically monitoring stress behavior, a user can adjust irrigation amounts and frequency to prevent over-irrigation. This reduces the cost of water, but also has an impact on fertilizer costs since the amount of fertilizer leached from the root zone is reduced. There is also an impact on the cost of chemicals to treat for disease since the occurrence of many diseases is lessened when irrigation amounts are optimal.

2. Preventing under-irrigation, maintaining healthy looking turf, while minimizing water use. Turf needs a certain amount of water. Where under-irrigation is a problem, monitoring stress behavior allows a grower to determine in plenty of time whether or not irrigation is needed.

3. Locating trouble spots. Managers often are worried about specific areas. The ST-27 allows a manager to rapidly scan a green, fairway or field to determine the exact location of a hot spot. An easy to read bar graph on the back of the pistol makes it easy to determine when an area is hotter (or cooler) than normal. Developing disease or insect problems can often be spotted before visual symptoms develop. Leaks in buried irrigation lines can be located.

4. Minimizing water consumption during dry-spells. Periodically, turf managers are faced with the necessity of conserving water. This means that a slight degradation in visual appearance can be tolerated in order to insure that water supplies are adequate. The ST-27 can be vital to this type of decision since a manager can base the decision on whether or not to irrigate on actual plant condition. Instead of irrigating at low stress levels (0-3 on our scale of 0-10) for optimum response, a manager would wait to irrigate until stress levels of 3-5 had been reached. This would allow the manager to conserve water yet be certain the turf is not in danger of dying.

5. Monitoring the effect of chemical applications on turf. There are a wide range of chemicals which are applied to turf for a variety of reasons. Different formulations are available from a number of commercial sources. The astute manager should be interested in determining which chemicals are able to (a) do their main function (controlling diseases, pests, etc) and (b) affects turf health least. Since chemical interactions with plant health are strongly dependent on the weather, soil and type of turf interactions, recommendations for the best chemicals should be site specific. The ST-27 can be an important part of these recommendations since it provides an objective method of determining how turf responds to the application of a given chemical.

6. Eliminating water stress as the cause of a problem. When stress levels are low, but color changes occur anyway, a manager can be sure the problem is not caused by moisture stress. This can speed up the process of solving the problem by eliminating one of the most common causes of turf problems.

7. Measuring the temperature of a frosted area to determine if a syringing will freeze on the grass or not.

8. Soil temperature. Is the soil temperature warm enough to plant seed? Is the soil temperature excessively hot, so that emerging seedlings will be damaged?

RATING TURF GRASS QUALITY

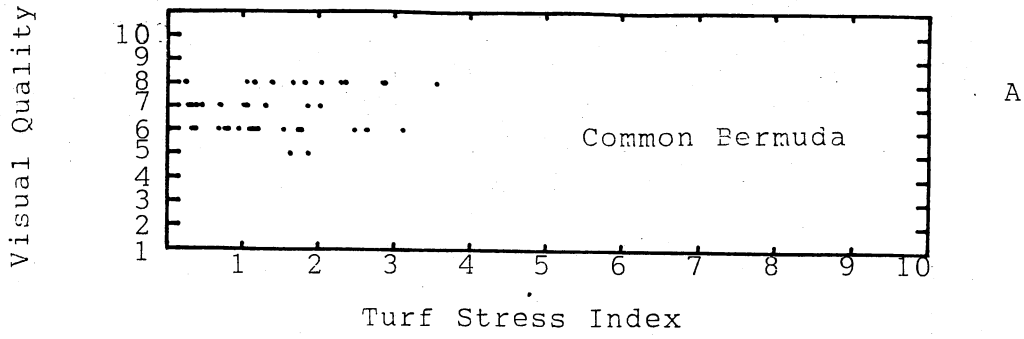
The quality of turf grass is generally determined by visual rating scores, which are strongly dependent on the opinion of the evaluator providing the score. Texas A & M research has shown that competent evaluators often strongly disagree on whether a turf should be rated as having poor or excellent quality.

Researchers at Texas A & M have recently shown that when plant color is measured objectively with a spectrometer that accurate determinations of turf quality can be made. The equipment necessary to make spectrometer readings is too expensive and difficult to use properly for routine use. They did find, however, that the turf stress index used in the Scheduler is highly correlated with spectrometer measurements of plant color on common Bermuda, Tall fescue, St. Augustine and Buffalograss, but not with visual scores (graphs A and B).

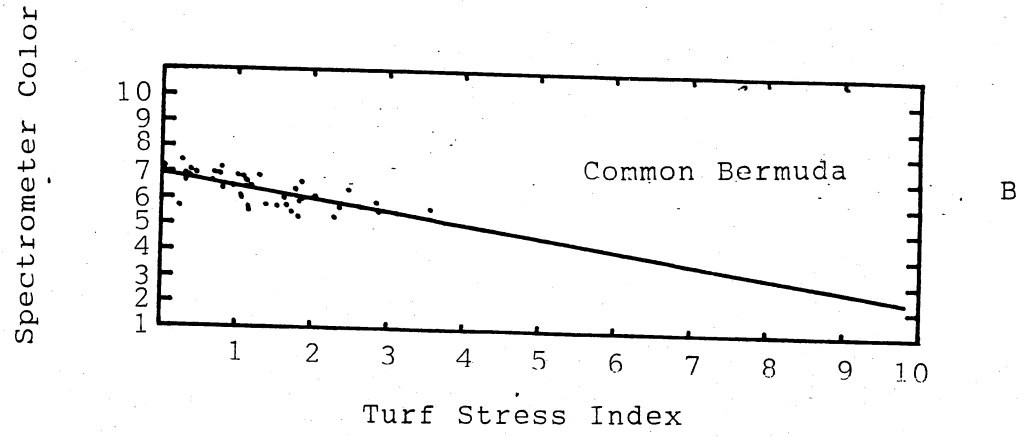
In a separate study, Dr. Phil Bussey at the University of Florida Experiment Station (Fort Lauderdale), showed that Scheduler readings were strongly correlated with soil moisture under St. Augustine Grass (graph C).

These studies show that Scheduler measurements of turf stress provide quantitative estimates of turf quality and soil moisture contents.

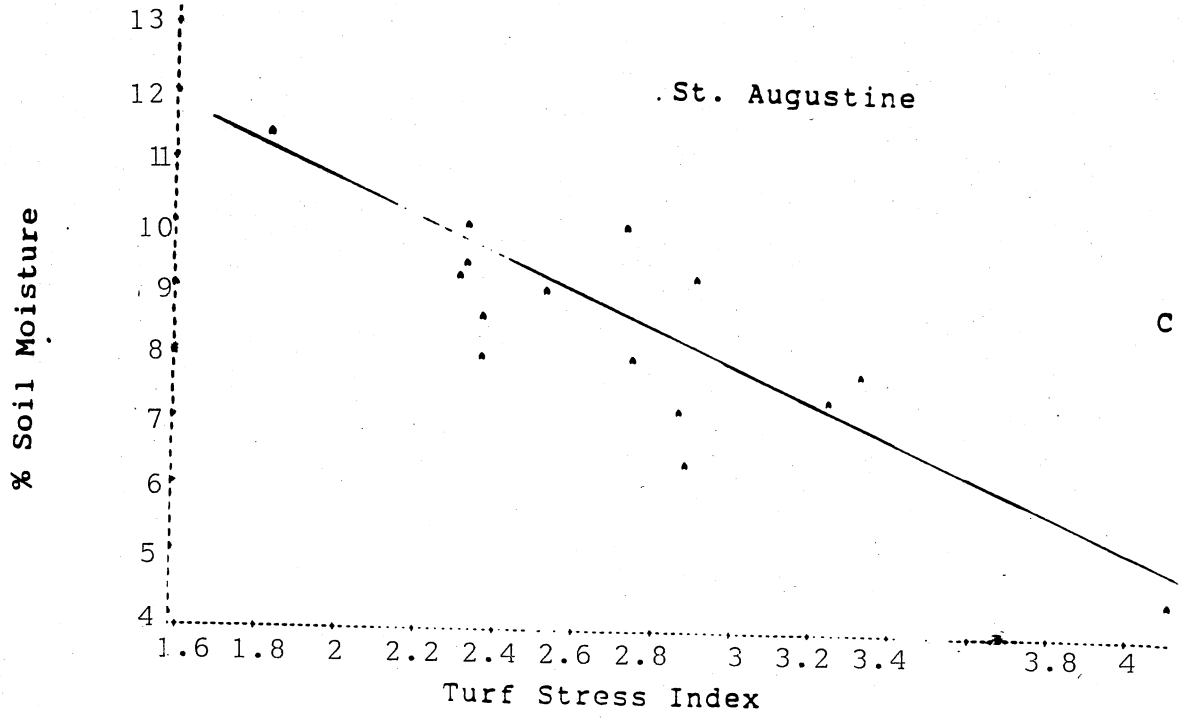
Horst, G.C., M.C. Engelke, and W. Meyers. 1984. Assessment of Visual Evaluation Technologies. Agren Jr. 76619-622.


Visual Quality
Common Bermuda
Turf Stress Index

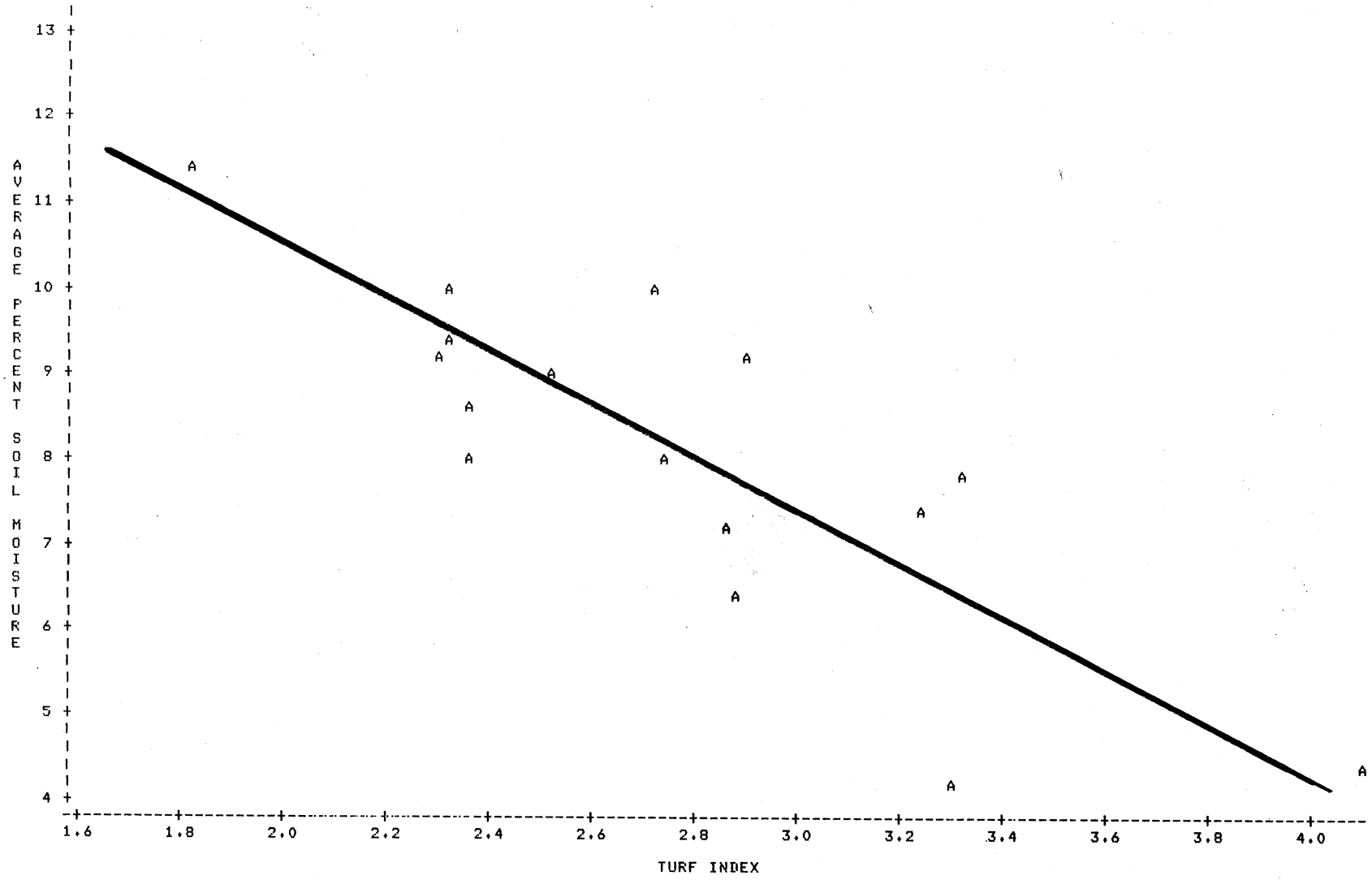
A


Spectrometer Color
Common Bermuda
Turf Stress Index

B


% Soil Moisture
St. Augustine
Turf Stress Index

C

AVERAGE CWSI VERSUS SOIL MOISTURE
ST. AUGUSTINE GRASS-NOV 21,1986--FT. LAUDERDALE , FLORIDA

PLOT OF PAVG*INDEX LEGEND: A = 1 OBS, B = 2 OBS, ETC.